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IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In re Application of:	)
Steven Martin HUDSON	) Group Art Unit: 2841
Serial No.: 10/032,471	) Examiner: Not Yet Assigned
Filed: January 2, 2002	)
For: Anode Monitoring And Subsea Pipeline Power Transmission	)

Assistant Commissioner for Patents
Washington, DC 20231

Sir:

CLAIM FOR PRIORITIES

Under the provisions of 35 U.S.C. § 119, Applicant hereby claims the benefit of the filing date of United Kingdom Patent Application Nos. 9916410.5, filed July 13, 1999 and 0100104.9, filed January 3, 2001, for the above-identified U.S. patent application.

In support of this claim for priority, enclosed is one certified copy of the priority application.

Respectfully submitted,

FINNEGAN, HENDERSON, FARABOW, GARRETT & DUNNER, L.L.P.

Dated: April 8, 2002

By: [signature]
Ernest F. Chapman
Reg. No. 25,961

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Dated 26 March 2002

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1. Your reference — TJF/JY/30433

2. Patent application number *(The Patent Office will fill in this part)* — **9916410.5**

3. Full name, address and postcode of the or of each applicant *(underline all surnames)*

   FLIGHT REFUELLING LIMITED
   BROOK ROAD
   WIMBOURNE
   DORSET BH21 2BJ

   Patents ADP number *(if you know it)* — 00451625001

   If the applicant is a corporate body, give the country/state of its incorporation — UNITED KINGDOM

4. Title of the invention — "ANODE MONITORING SYSTEMS AND METHODS"

5. Name of your agent *(if you have one)*

   "Address for service" in the United Kingdom to which all correspondence should be sent *(including the postcode)*

   fJ CLEVELAND
   40-43 CHANCERY LANE
   LONDON
   WC2A 1JQ

   Patents ADP number *(if you know it)* — 07368855001

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Country	Priority application number *(if you know it)*	Date of filing *(day / month / year)*

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   a) any applicant named in part 3 is not an inventor, or
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Continuation sheets of this form	–
Description	19
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Priority documents	–
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Statement of inventorship and right to grant of a patent *(Patents Form 7/77)*	–
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11. I/We request the grant of a patent on the basis of this application.

Signature F J Cleveland Date 13.07.99

fJ Cleveland

12. Name and daytime telephone number of person to contact in the United Kingdom TJ FAULKNER 0171 405 5875

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Anode monitoring systems and methods

This invention relates to anode monitoring systems and anode monitoring methods for monitoring the integrity of anodes provided on a metallic structure for cathodic protection purposes. Examples of such structures are pipelines and components used with pipeline systems such as trees, manifolds and processing plants.

A subsea pipeline is typically protected by the use of cathodic protection. This means that sacrificial anodes are disposed at spaced locations along its length. The continued presence and effectiveness of the anodes is essential to the functioning of the cathodic protection. Thus, to ensure the continued integrity of the pipe itself, the anodes must be regularly inspected. At present this is either done by the use of remotely operated vehicles and/or potential surveys. Each of these methods is extremely costly and can only be performed when weather conditions allow.

It is an object of this invention to provide an anode integrity monitoring technique which alleviates at least some of the problems of the existing techniques.

It will be appreciated that the anodes may become non-effective in a number of ways, for example the anode may become totally detached from the pipeline, it may lose effective electrical contact with the pipeline or may have disintegrated to such an extent that it ceases to be effective. It is desirable to be able to detect when any of these events has occurred.

According to a first aspect of the present invention there is provided an anode monitoring system for monitoring the integrity of anodes provided on a metallic structure for cathodic protection purposes comprising a signal circuit having at least one signal path comprising the metallic structure and a selected anode whereby the characteristics of the signal circuit depend on the effectiveness of the selected anode, signal generation means for generating and applying a signal to the signal circuit, and a central station for monitoring signals on the signal circuit to thereby determine whether the selected anode is effective.

According to a second aspect of the present invention there is provided an anode monitoring method for monitoring the integrity of anodes provided on a

metallic structure for cathodic protection purposes comprising the steps of:

generating a signal and applying said signal to a signal circuit, the signal circuit comprising at least one signal path comprising the metallic structure and a selected anode whereby the characteristics of the signal circuit depend on the effectiveness of the selected anode; and

monitoring signals on the signal circuit at a central station to thereby determine whether the selected anode is effective.

Preferably the signal generating means is arranged, when the selective anode is effective, to apply a signal to the signal circuit which is indicative of the effectiveness of the selected anode.

Preferably the signal generating means, or at least one component thereof is disposed at the selected anode.

The absence or defectiveness of the selected anode may be detectable as a break in the signal circuit. The break in the circuit may be detectable as the result of an inability to apply a signal to the signal

circuit and/or an inability to receive a signal from the circuit. The absence or defectiveness of the selected anode may be detectable due to the absence of an expected signal. The expected signal may be that resulting from a change in the effective impedance of the signal circuit.

The signal circuit may comprise a return path via earth. Preferably the selected anode, when effective, provides a conduction path from the metallic structure to earth. Where the selected anode provides a path to earth, the absence or defectiveness of the selected anode may be detectable as the loss of an earth connection.

The signal circuit may comprise impedance means. The impedance means may be disposed between the selected anode and the remainder of the metallic structure. The impedance means may be provided in series between the selected anode and the metallic structure.

The impedance means may comprise isolation means. The impedance means may comprise inductance means. The impedance means may comprise filter means, which may be arranged to give a high impedance to time varying

signals within one or more selected ranges of frequencies and a low impedance to signals outside the selected range or ranges. The impedance means can be arranged so that the real part of the impedance is substantially zero. This means that there is little or no attenuation of the dc components of signals passing through the impedance means.

The use of inductance means and/or filter means has advantages when the metallic structure is used to carry signals because these means can be chosen to offer high impedance to the time varying signals used for signalling thereby reducing losses, whilst offering low impedance to the currents used for cathodic protection.

Transmitting means and receiving means may be provided for allowing data to be transmitted along the metallic structure. The transmitting and receiving means may be provided to assist the anode monitoring operation and/or to provide a distinct data transmission function.

The transmitting means and/or receiving means may be connected across the impedance means and arranged to

transmit and/or receive signals across the impedance means.

Where signals are received across the impedance means, the use of filter means as the impedance means has an additional advantage that noise generated outside the frequency band of interest will be attenuated before it enters the receiver.

In some embodiments the signal generating means comprises transmitting means, the signal circuit comprises an earth return path so that the transmitting means requires an earth connection and the selected anode is arranged, when effective, to provide the earth connection so allowing transmission of a signal indicative of the anode's effectiveness which is detectable at the central station. When the selected anode is defective or absent the transmitting means has no earth reference so that no signal is transmittable by the transmitting means. Therefore if the signal is absent it can be determined that the selected anode is defective or absent. In such embodiments the transmitting means is preferably connected across the impedance means.

In other embodiments the signal generating means comprises reference signal generating means arranged to apply a reference signal to the signal circuit and effective impedance varying means for varying the effective impedance of the signal circuit in accordance with data to be transmitted, the central station comprises monitoring means for monitoring changes in the reference signal caused by varying the effective impedance of the signal circuit and the signal circuit is arranged such that defectiveness or absence of the selected anode causes a break in the signal circuit whereby non-effectiveness of the selected anode is detectable at the central station due to the absence of changes in the reference signal.

In such embodiments the reference signal generating means may be arranged to be locatable at a position which is remote from the selected anode. The impedance varying means may be located adjacent the selected anode.

Preferably the signal circuit comprises a plurality of signal paths each comprising the metallic structure and a respective anode. The subsidiary features defined above in relation to the selected anode apply

equally to each of the respective anodes in a system with a plurality of signal paths. Independent signal generating means or at least one independent component of the signal generating means may be disposed at each anode.

Different data and/or a different signal and/or a different frequency may be associated with each of the respective anodes. The system may be arranged so that signals associated with each anode are generated at different times. The signals may be randomly generated. In this way, for example, when a particular anode is non-effective and hence its associated data/signal is not received at the central station it is possible to determine which anode it is which is non-effective.

According to a third aspect of the present invention there is provided a data transmission system comprising transmitting means, receiving means and a metallic structure which is primarily intended for another purpose but which in use acts as a signal channel between the transmitting means and the receiving means, wherein the metallic structure includes at least one anode provided for cathodic

protection purposes and impedance means are disposed between the metallic structure and the anode.

The data transmission system may comprise a signal circuit comprising the metallic structure and a return path. The return path may be via earth. The signal circuit may comprise the anode. Preferably the anode provides a path from the metallic structure to earth.

The impedance means may be provided in series between the respective anode and the metallic structure.

The impedance means may comprise inductance means. The impedance means may comprise filter means, which may be arranged to have a high impedance to time varying signals within one or more selected ranges of frequencies and a low impedance to signals outside the selected range or ranges. The use of the inductance means or filter means gives the advantages discussed above.

According to a fourth aspect of the present invention there is provided apparatus for use with a metallic structure in carrying out the first, second or third aspects of the invention.

In all aspects of the invention the metallic structure may comprise a pipeline, for example, a subsea pipeline of the type used for conveying oil or gas. The metallic structure may comprise a processing plant and/or a tree and/or a manifold.

Embodiments of the present invention will now be described, by way of example only, with reference to the accompanying drawings in which:

Figure 1 schematically shows a first anode monitoring system; and

Figure 2 schematically shows a second anode monitoring system.

Figure 1 shows a first anode monitoring system which generally comprises a metallic structure consisting of a pipeline system 1 provided with a plurality of anodes 2 and connected via a link 3 to a central station 4. It will be appreciated that a pipeline system may be provided with a very large number of anodes 2 although only three are shown in Figure 1.

Each anode 2 has an associated notch filter 5 connected in series between the respective anode 2 and

the metallic structure 1. Further, each anode 2 has an associated transmitter 6 which acts as a signal generating means and which is connected across the respective notch filter 5.

The metallic structure 1 of the pipe is encased in an insulating coating 7. Thus the resistance between the metallic structure and the surrounding medium is high. There is a capacitance between the metallic structure 1 and the surrounding medium with the coating 7 acting as a dielectric. However, unless the frequency of signals is high enough that the capacitance comes into play, losses to the surroundings from the metallic structure 1 are almost exclusively through the anodes 2. Thus a signal circuit S comprising respective signal paths S_1-S_n for each of the anodes 2 can be considered to exist. In each case the signal path S_n comprises the metallic structure 1, the respective anode 2, the link 3 and a respective return path via earth to the central station 4.

The notch filter 5 associated with each of the anodes 2 is chosen to have a high impedance to signals of the frequency generated by the associated transmitter 6 but to give a low impedance to the currents applied to

the metallic structure 1 for cathodic protection purposes. This means that when the respective anode 2 is present, the cathodic protection currents pass easily through the notch filter 5, allowing the cathodic protection system to work effectively. However, when transmitting a signal using the transmitter 6 there is effectively an open circuit between the metallic structure 1 and the respective anode 2 so that a signal can be transmitted along the metallic structure 1 with the anode 2 providing an earth reference for the transmitter 6.

On the other hand, if the respective anode 2 were not present the transmitter 6 would not have an earth reference, or to view it another way the earth return path would be broken, so that no signal would be received at the central station 4. The same is also true if the effectiveness of the anode 2 has been compromised in some other way. Thus by looking for the absence of an expected signal, it is possible to determine at the central location 4 that the anode 2 is not effective.

In a particular implementation each transmitter 6 is arranged to transmit a simple message at a random time

during a selected period for example once a week. The time taken to transmit each message would be of the order of 5 seconds. Therefore in a system having say 50 anodes the total transmit time would be 250 seconds each week. Because of this, the probability of two transmitters 6 transmitting at the same time is very low and thus the chance of missing a signal from a functioning anode because of a clash is very low. In practise before deciding that an anode was not functioning a second or further missing signal would be waited for. In this way the probability of incorrectly diagnosing a faulty anode may be reduced to say 1 in 1,000,000. The random signalling technique is used because it is impractical to provide access to real time at each anode.

Each message has various components for example, Address (8 bits), Protocol overhead (8 bits), Error check (16 bits), Battery condition etc. (8 bits), measurement results (16 bits). The measurement results transmitted in the message may include the value of the current flowing through the respective anode and the potential difference between the anode and the metallic structure adjacent the anode. These measurements can help in assessing the condition of

the associated metallic structure and other anodes. In alternatives each transmitter 6 can be arranged to transmit at a distinct frequency from each of the other transmitters and/or to transmit a simple message which is unique to a particular anode 2. The central station 4 can then look for a plurality of different signals and be arranged to indicate precisely which anode it is which is missing when a particular signal is absent. In such alternatives the notch filter 5 is replaced by a band stop filter chosen to give high impedance to each of the different frequencies used.

In other alternatives the notch filter 5 may be replaced with another circuit element, for example an inductor, which has the necessary properties of providing high impedance to the signals to be transmitted whilst providing low impedance to the cathodic protection currents.

Figure 2 shows a second anode monitoring system which is similar to the first anode monitoring system shown in Figure 1 but which uses a different signal transmission technique. In the first anode monitoring system it is necessary to have a source of power at each of the anodes 2 which can be used to drive the

respective transmitter 6. Because of the length of the pipelines on which the system would typically be used and the losses inherent with the type of signal transmission used, the power demands are high. These power demands can be met by the use of one-shot batteries but this means that the system can function only for a limited period before the batteries have to be replaced.

In the second monitoring system shown in Figure 2, the power source necessary for transmitting signals from each of the anodes can be provided at a location remote from the anodes. However, a power source may be provided at each anode to drive the electronics disposed at the anode. The power requirements of any such electronics, however, will be very small compared with that required for transmitting signals.

The second anode monitoring system generally comprises the metallic structure of a pipeline 1 provided with a plurality of anodes 2 at spaced locations and connected via a link 3 to a central station 4. Each of the anodes 2 is connected to the metallic structure 1 via a notch filter 8 and a bypass loop having a switch 9. When the switch 9 is open the only conduction path

between the metallic structure 1 and the respective anode 2 is through the notch filter 8 but when the switch 9 is closed there is a free conduction path. A tone detecting circuit 13 is connected across each filter 8.Each switch 9 has an associated control means 10 which is arranged to open and close the switch 9 in dependence on data which is to be transmitted. The switch 9 and control means 10 act as an impedance varying means.

The central station 4 comprises a current source 11, which acts as a reference signal generating means, a first terminal of which is connected via the link 3 to the metallic structure 1 and a second terminal of which is connected to earth, and voltage measuring means 12, one terminal of which is connected to the first terminal of the current source 11 and the other terminal of which is connected to a reference earth. A tone transmitting circuit 14 is connected across the current source.

The pipeline has an insulating layer 7 and a signal circuit S having respective signal paths S_1-S_n associated with each of the anodes 2 can be considered to exist. Each signal path S_n comprises the respective

anode 2, the metallic structure 1, the link 3 and a respective earth return path.

In the normal situation the signal paths S_n are completed via the notch filter 8. In this way there is a current path from the metallic structure 1 to the anode 2 which allows the cathodic protection system to function because the notch filter 8 offers substantially no impedance to the cathodic protection currents. However, the notch filter is chosen to have high impedance to reference signals generated by the current source 11. When it is desired to send a signal from a particular anode 2, a reference signal is applied to the signal circuit and the control circuit 10 operates the respective switch 9 to encode data onto the signal circuit S. Whilst all of the switches 9 are open there are only earth return paths to the second terminal of the current source 11 through the insulating layer and through the notch filters 8. However, when the switch associated with a particular anode is closed the effective impedance of the signal circuit S as a whole is reduced significantly for the reference signal because the respective notch filter 8 is by-passed. Thus the effective impedance can be varied by opening and closing the switch to encode

data onto the signal circuit. The voltage measuring means 12 at the central station 4 is used to detect resulting changes in potential difference between the first terminal of the current source 11 and earth as the switch 9 is opened and closed. The control means 10 associated with each anode 2 is used to code a signal onto the signal circuit S which is indicative of the respective anode. Thus the central station 4 can look for a particular signal to confirm the effectiveness of a particular anode 2. However, if that anode 2 is not present, then opening and closing the switch 9 will not change the effective impedance of the signal circuit and correspondingly no change in potential difference at the central station 4 will be detected.

The transmission of signals from the anodes is controlled in the manner described below. The tone transmitting circuit 14 transmits a tone along the metallic structure 1. The tone is detected by each of the tone detecting circuits 13. Each tone detecting circuit 13 is arranged to emit a trigger signal to the respective control means 10 after a predetermined period has elapsed. Once the respective control means 10 has received the trigger signal it is caused to

operate to encode the desired data onto the metallic structure. The predetermined period for each tone detecting circuit 13 is different so that signals from each anode 2 are transmitted at different times. The time at which a signal should be received from each anode 2 is known and thus signals can be looked for at these times at the central station. The absence of a particular signal gives an indication that the corresponding anode 2 is non-effective.

In alternatives of each anode monitoring system the central station 4 is equipped with transmitting means (not shown) which are capable of transmitting instructions specific to particular anodes to cause the respective transmitters 6 or control means 10 to operate on command. Typically, the central station 4 transmits a series of individual signals each of which causes the electronics associated with a particular anode to generate a signal which can then be looked for at the central station 4.

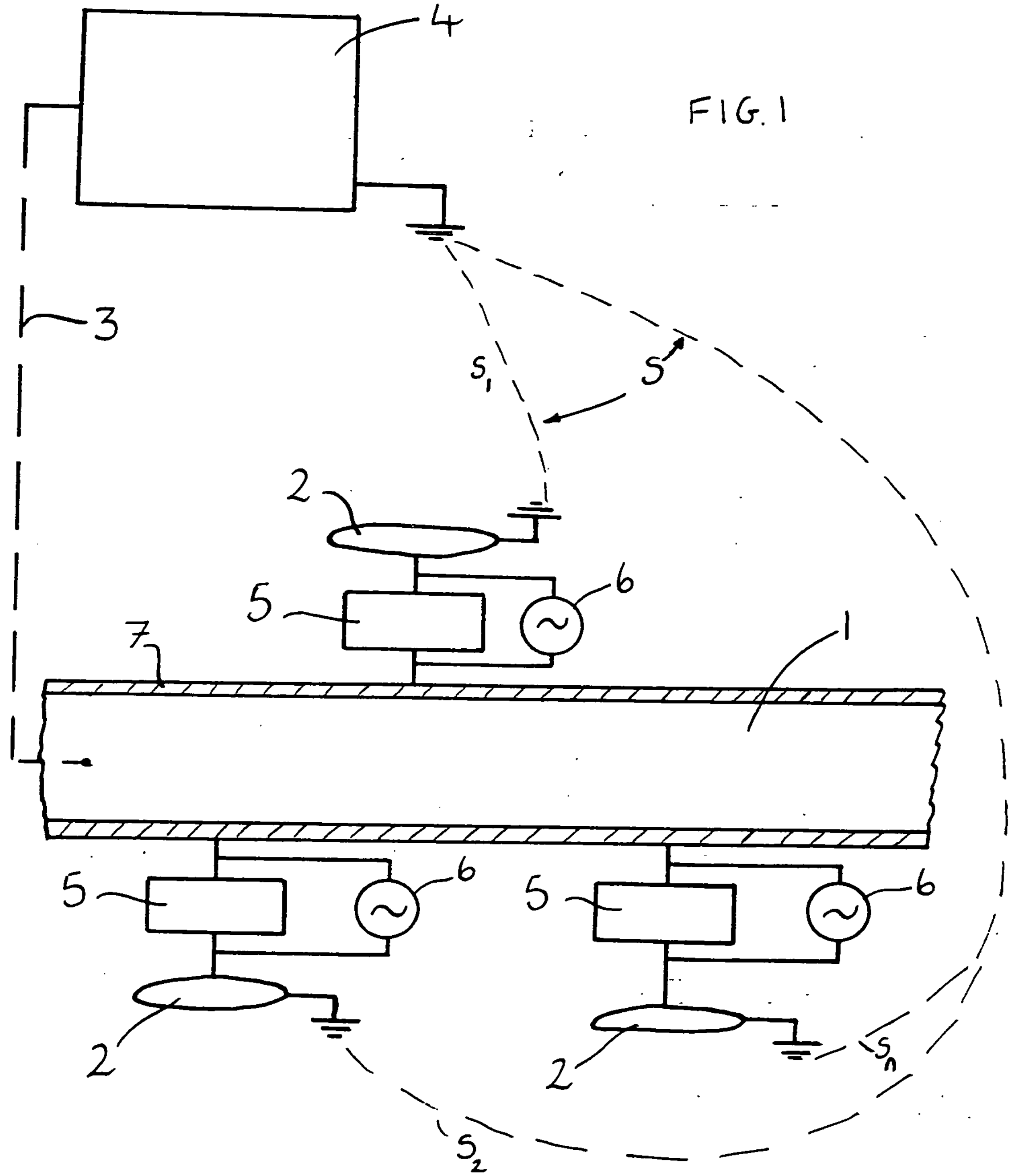

FIG. 1

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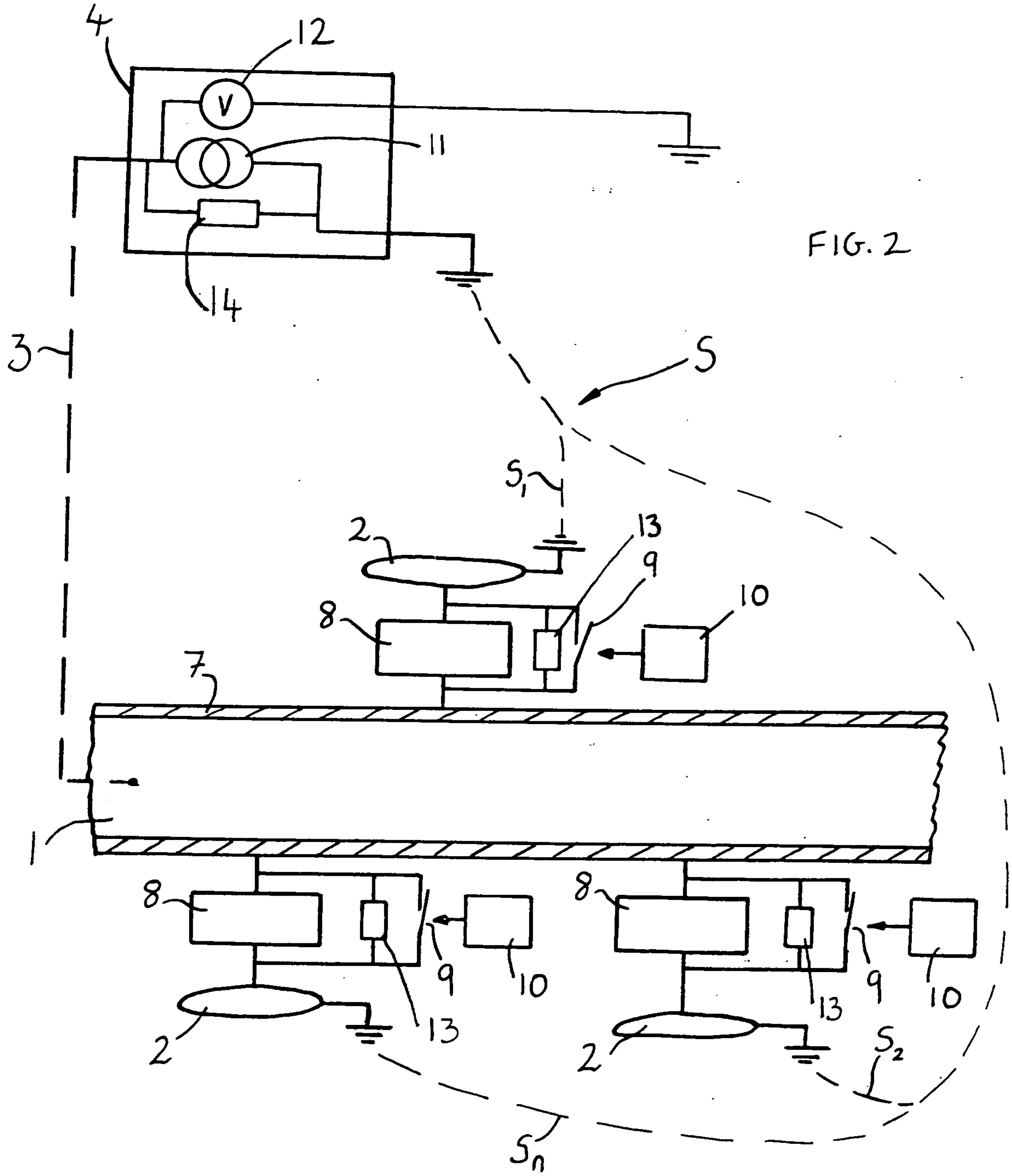

FIG. 2